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High Early Strength of Slag Based Fiber Reinforced Concrete

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Abstract: ***The experimental investigation achieved the high early strength of fiber reinforced concrete by adding slag (GGBS), rapid hardening admixture, and steel fibers. This concrete is done curing for seven days and followed by hot air oven curing for four hours as per different mixes. Tests such as destructive and non-destructive test have been performed. During the testing of the cube which is cured for seven days has achieved the high compressive strength of 42.24 N/mm^2 for M25 Grade of concrete.***

Keywords: Hot air oven curing, Steel fiber, Strength, Ultrasonic pulse velocity, Water absorption.

I. INTRODUCTION

The most common building material is concrete which is generally weak in tension and often ternate binders can save the cost of cement concrete production. Now a day's slag mixed cement has been widely manufactured and potentially used in concrete production. This growing interest is due to the improved mechanical performance of cement concrete with the addition of the special type of fibers [1, 2]. Concrete is one of the most past supplied by utilizing locally accessible ingredients. The present trend in concrete technology towards increasing the strength & durability of concrete to meet the demands of modern construction demands modern construction. The main purpose of the fibers used in concrete to improve the flexural rigidity in the axial load condition of the concrete. The mode of accelerated curing on mechanical properties of the GGBS based on concrete for various mixes of concrete was investigated systematically [3, 7]. The properties of slag based fiber reinforced concrete the effect of fiber content up to 0 to 1.5 % showed remarkable improved and also an establishment of the relationship between the mechanical and durability properties of concrete [8, 9]. GFRC is one which is manufactured by adding the glass fibers content to the conventional concrete with different percentage for various mixes. Since, the fibers cannot rust like steel; there is no need to prevent the corrosion in cover concrete over a thickness for a protective agent. The M25 grade concrete was used with the addition of glass fiber of 33 % and 0.67% by the weight of concrete with partial replacement of GGBS in 15 to 30 % by weight of binding materials [10, 13]. The properties include compressive strength and flexural strengths electrical resistivity, water penetration, gas permeability, and scaling resistance to deceiving chemicals fibers are added at volume fractions of 0.125 % respectively specimens having steel fibers characterized by the length/diameter ratio of 6.5 and fiber dosages of 30 to 60 kg/m^3[14-18]. The rapid hardening, excess of water to binder ratio, more drying on the volumetric surface of the structure is because of drying in shrinkage and causes of volume change. When the structure is loaded, micro crack open up and propagates because of development of such concrete [19-20].

MATERIALS USED DETAILS

A. Cement

Ordinary Portland Cement (OPC) of grade 53 grade was used for preparing the structural concrete mix for all the batches in preparation of the prisms and cubes for destructive testing. The obtained test results of Portland cement is represented in Table I.

Table- I: Test values for Portland cement (Physical properties)

Name of the test	Obtained-Results
Specific gravity of Portland cement	3.15
Soundness-Le-chatelier method-(mm)	3.5
Fineness (IS sieve 90 microns) [mm]	3
Standard consistency test (%)	34
Setting time - Initial (minutes)	98
Setting time - Final(minutes)	250

B. Fine Aggregate

The average retained particle size of 12.5 mm of river sand was tested and used. The obtained results are given in Table II.

Table- II: Test values for fine aggregate (river sand)

Name of the test	Obtained-Results
Specific gravity	2.75
Water absorption-(%)	1.00
Fineness modulus	2.84
Density (rodded) kg/m3	1750

C. Coarse Aggregate

The coarse aggregate passing through 20 mm IS sieve and retaining on 12.5 mm sieve of crushed blue stone was used. The obtained test results values are given in Table III.

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Table-III: Test values for course aggregate

Name of the test	Obtained-Results
Specific gravity	2.77
Water absorption	1.0 %
Fineness modulus	6.81
Density (loosely) kg/m^3	1830
Density (rodded) kg/m^3	1830

D. Binding materials (GGBS):

The smelting and refining process of slag produced from steel plant industries, this type of slag is more suitable for alternate binding materials, which is partial replacement of Portland cement and image of slag (GGBS) as shown in Figure 1.

Fig. 1. Image of GGBS

E. Steel fibers:

Crimped type of steel fibers of 30 mm in length and a diameter of 0.5 mm were used for the preparation of the various mixes. The aspect ratio of the crimped-steel fiber is 60 as shown in Figure 2.

Fig. 2. Image of crimped Steel fibers

F. Rapid hardening admixtures (RHD):

The early strength gain is depending upon the addition of chemical admixtures. The chemical limits range was fixed based on the trial and error methods and exhibited the better improvement range starting from1500 ml – 3000 ml for 50 kg quantity of binder content is used for different mixes and image of RHD is shown in Figure 3.

Fig. 3. Image of Rapid hardening admixture

G. Curing procedure details:

The curing method was employed as a regular water bath for 7 days followed by hot air oven at 100 to 110^{0}C. The use of hot air oven increases the temperature up to four hours, thus resulting in increases the rate of hydration occurred during the hardening of the concrete.

II. EXPERIMENTAL PROCEDURE AND TEST METHODS

The M25 grade concrete mix was adopted and consisting of four different mixes were prepared in accordance with IS 10262-2019 [21]. The detailed mix proportions as represented in Table IV.

Table- IV: M25 grade of concrete mix proportion details

Mix ID	Binder content required (kg/m^3)		Fine Aggregate	Coarse Aggregate	Steel-fiber		w/cm ratio	Chemical admixtures used per 50 kg of cement
	Cement	Slag	(kg/m^3)		%	(kg/m^3)		
R-1	480	120	600	1200	1.5	36	0.50	12150
R-2	450	150	600	1200	1.5	36	0.40	14400
R-3	480	120	600	1200	2.0	48	0.50	22480
R-4	450	150	600	1200	2.0	48	0.40	24000

A. Compressive strength test:

The compressive of the strength of concrete is determined for various mixture proportions of concrete. The standard size of steel cubes 150 x 150 x 150 mm is cast and used for conducting the test. The sample mix Id R1 –R4 load acting on the cube space rate was constant.

B. Flexural rigidity test:

The standard steel size of the prism is 500 x 100 x 100 millimeter were cast and tested. The third point loading arrangement was used to determine the bending stress and the dial gauge was read to 1 division on the dial gauge as 1.25 kN of a load.

C. Ultrasonic pulse velocity (UPV):

The UPV test mechanism is to examine the quality hardened structures owing to rapid hydration occurred inside the concrete, thus indicating the good range velocity.

Fig. 4. Image of Ultrasonic pulse velocity (UPV)

D. Rebound hammer test:

The Nondestructive test (NDT) method was employed to calculate the cube strength of concrete as referred from the standard chart with the help of a rebound hammer or rebound index. The rebound index number was recorded due to the perfect external force with the 90-degree angle applied on the top hardened concrete top surface and recorded all the tested average values for various mixes.

E. Water absorption:

The water absorption is defined as the ratio of initial weight (after de-molding) to final weight (before testing). To determines the percentage of the water holding capacity in and around the surface of the concrete. The main objective of these tests is to measure the density of the concrete.

III. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

A. Compressive strength of concrete:

The compressive strength test results of the specimen are shown in Figure 5. The design mix of M25 was used for the preparation of the samples and achieved the M40 grade of concrete, the best proportions were observed for mix containing 80% OPC, 20% of slag, rapid hardening chemicals for 2000 ml of 50 kg of cement content along with 2% of crimped steel fibers exhibited the higher ultimate load of 1064 kN (R-3 mix ID) for 7days strength of 42.24 MPa. The mix ID R-4 also had attained the grade of concrete up to M40 at 7 days

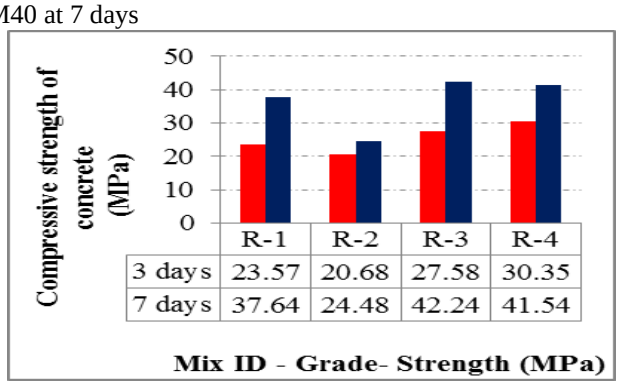


Fig. 5. Compressive strength of concrete at different curing days

B. Flexural rigidity:

The bending stress of concrete test values for different curing days as shown in Figure 6. From the various experimental results, the sample R-4 specimen obtained more strength compared to the other specimen. The mix proportions for the specimen R4is 2% of steel fiber, 2500 ml rapid hardening admixture for 50 kg of cement. The bending stress (flexural strength) of concrete attains the maximum strength 3.75 N/mm^2 and 8.2 N/mm^2 for 3 and 7 days curing respectively and remains same for 7 days curing values are satisfied as per code provisions. However, it is more bending stress is expected after 28 days of curing because all mix proportions of slag based fiber reinforced concrete test results values are increased in the case of compressive strength.

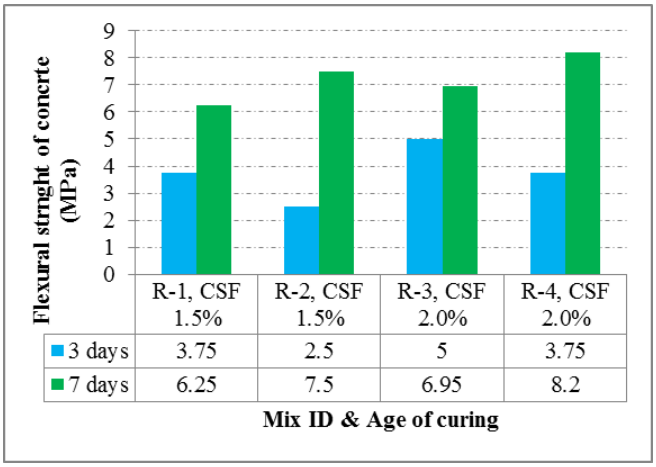


Fig. 6. Flexural rigidity of concrete at different curing days

C. Ultrasonic pulse velocity:

The ultrasonic pulse velocity values for different curing days as shown in Figure 7. From this experimental results, the sample R-1 specimen obtained high velocity compared to the other specimen The mix proportions for the specimen R1 is 1.5% of steel fiber, 1000 ml of rapid hardening admixture for 50 kg of cement. The bending stress (flexural strength) of concrete attains the maximum velocity of 3.836 km/sec for 7 days curing and this value is indicating the good rating in accordance with IS-13311-1992 part 1 [22].

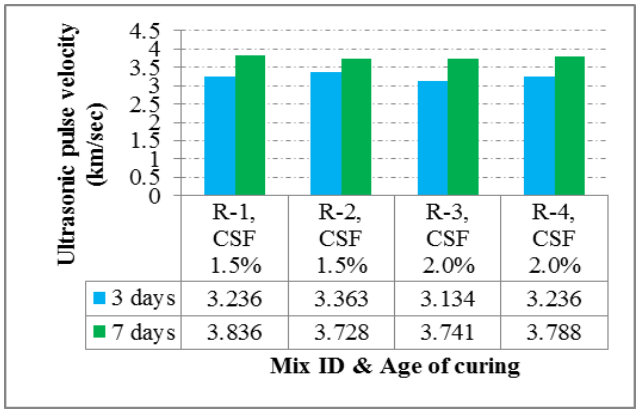
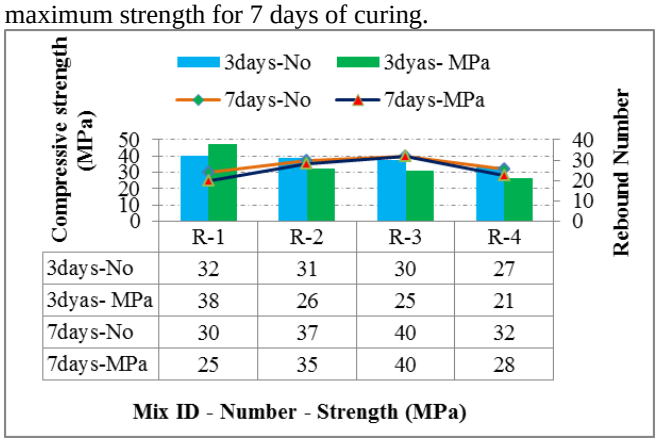


Fig. 7. Ultrasonic pulse velocity of concrete at different curing days

D. Rebound hammer test results:

By using the rebound hammer, the hardened surface of the compressive strength of the concrete cubes is determined and all the test values are graphically represented in Figure 8. The rebound hammer index gives the predicted strength of the concrete, the strength was noted corresponding the index value as per IS 13311-1992 part 2 [23]. The compressive strength of the specimen R-2 and R-3 have attained maximum strength for 7 days of curing.



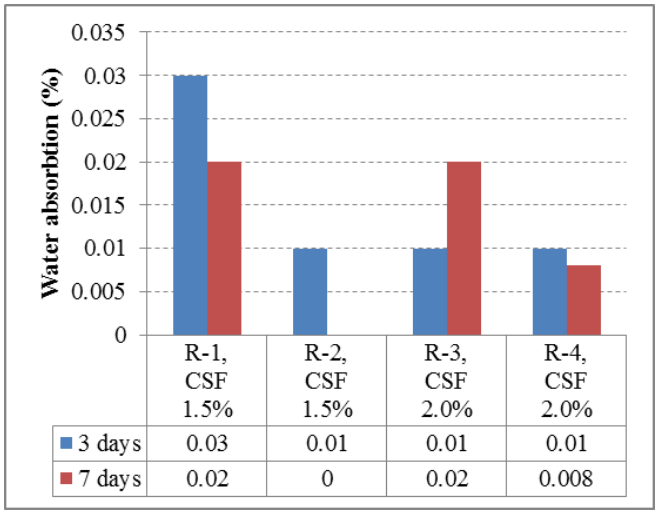
	R-1	R-2	R-3	R-4
3days-No	32	31	30	27
3dyas- MPa	38	26	25	21
7days-No	30	37	40	32
7days-MPa	25	35	40	28

Mix ID - Number - Strength (MPa)

Fig. 8. Rebound hammer after results of different curing days

E. Water absorption:

The various water absorption test values for different curing days as shown in Figure 9. From these experimental results, it was noted zero water absorption (R-2 mix) for 7 days curing.



	R-1, CSF 1.5%	R-2, CSF 1.5%	R-3, CSF 2.0%	R-4, CSF 2.0%
3 days	0.03	0.01	0.01	0.01
7 days	0.02	0	0.02	0.008

Fig. 9. Water absorption at different curing days

IV. CONCLUSION

The following conclusions based on the laboratory experimental test results as given below:

M25 grade of the concrete cast and tested for 7 days curing is achieved the M40 grade of concrete for 7 days of curing followed by 4 hours of hot air oven curing and similarly, all mixes were tested. The bending stress of concrete beams showed maximum bending stress 8.2 N/mm^2 for a mix proportion of 20% of slag, with the addition of 2% of crimped steel fibers for 7 days curing.The inclusion of crimped steel fibers in varying proportions in the concrete mix decreases the internal cracks and minimizes the crack depth of the concrete beams.

The concrete prepared is concluded to be green concrete by using supplementary cementitious binding materials which are collected from different industries like a waste by-product, and reducing the CO_2 emission.

Usage of rapid hardening chemical-admixture for various mixes of concrete exhibits the rapid hardening of concrete due to increasing the hydration gel formation thus resulting in the higher strength at an early age.

It is more suitable for fast track construction and more economical for structural concrete.

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